NORTHROP GRUMMAN
Space Technology

Space Cryocoolers

E. Tward

June 20, 2003

Overview

Maturity

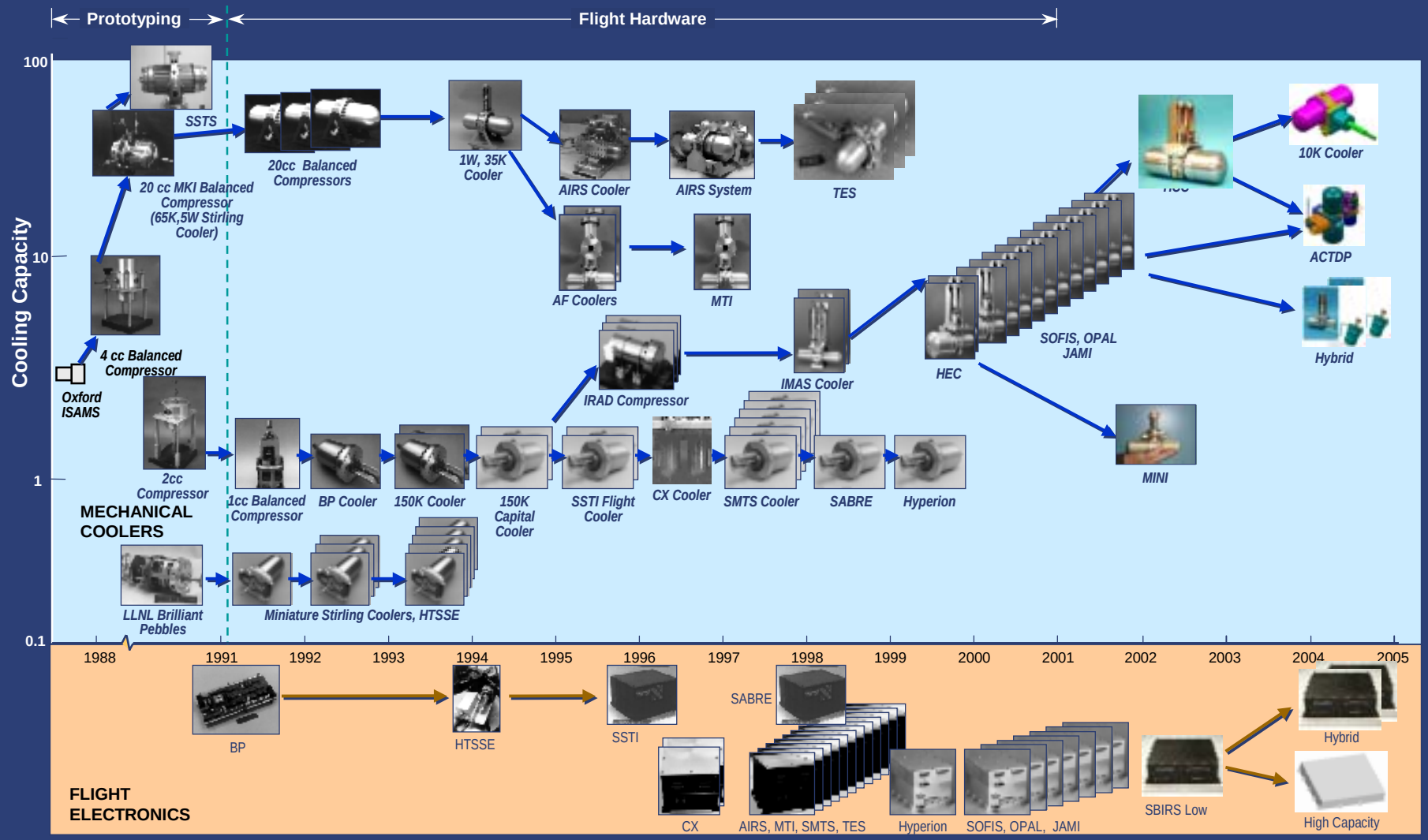
- ***Northrop Grumman Space Technology (TRW) has been developing Cryocooler technology since the late 1980s***
- ***Northrop Grumman Space Technology has delivered 20 flight qualified cooler systems***
  - Eight coolers currently operating in orbit (2 longer than 5 years to date)
  - No flight failures
  - 30 additional flight type coolers and spares manufactured and delivered
- ***First of next generation cooler systems has been flight qualified (HEC)***

Development

- ***State of art is being pushed to fill in large holes***
  - Higher efficiencies
  - Smaller coolers for much smaller payloads
  - Higher capacities for larger systems
  - Lower temperatures for VLWIR

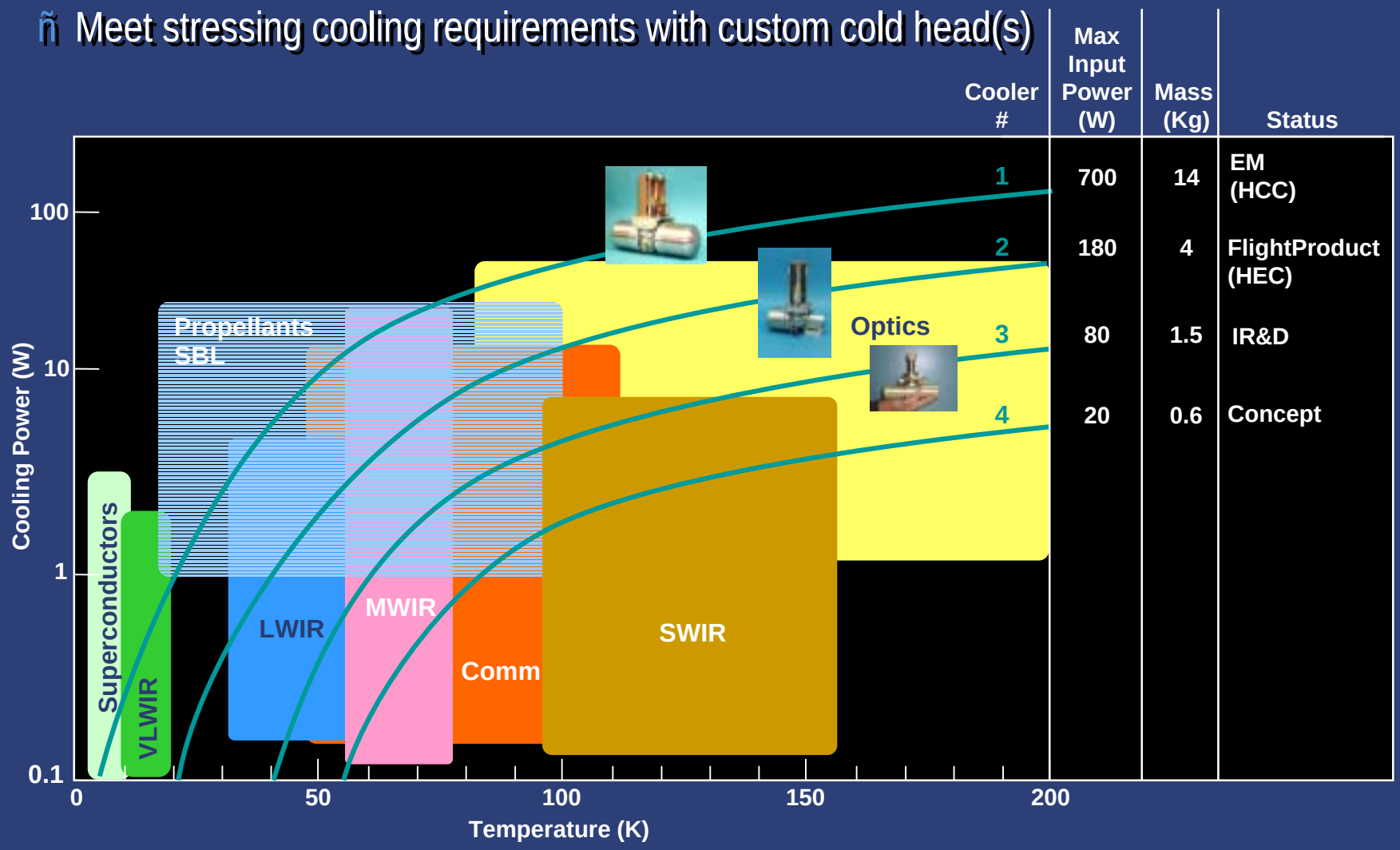
Heritage

- *Northrop Grumman Space Technology has produced more flight coolers than the rest of US industry combined*



Cooler Requirements

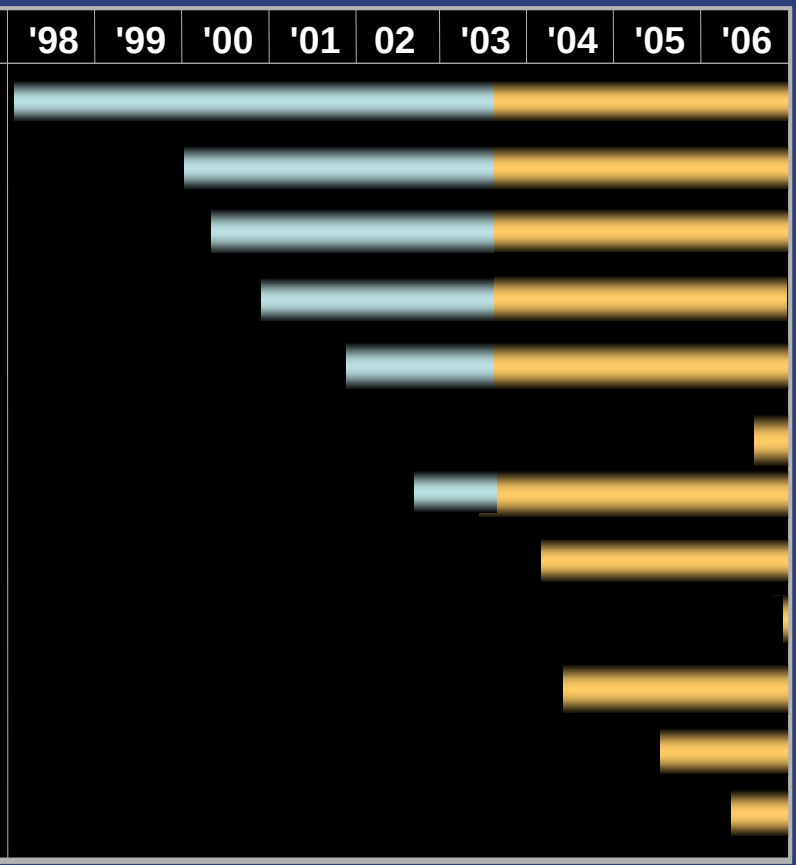
- ***Most cooling requirements could be met with variants of 4 basic scaled cryocoolers***
  - ñ Meet stressing cooling requirements with custom cold head(s)



Northrop Grumman Space Technology Cryocooler Flight History/Future

- *No Northrop Grumman Space Technology cooler has ever failed in orbit*

Flight Project	Cooler	Electronics
CX (2)	Mini-Pulse	Airs Class (2)
HTSSE	Stirling	Custom
MTI	Airs Class	Airs Class
Hyperion	Mini-Pulse	Hyperion Class
SABER	Mini-Pulse	Demo
STSS (4)	Mini-Pulse	Airs Class (4)
AIRS (2)	Airs Class	Airs Class (2)
TES (2)	Airs Class	Airs Class (2)
SOFIS	HEC	Hyperion Class
JAMI (2)	HEC	Hyperion Class (2)
OPAL (2)	HEC	Hyperion Class (4)
Hybrid 2 Stage (2)	HEC	Next Gen



Cryocooler Road Map

NORTHROP GRUMMAN Space Technology

Only US Long-Life Flexure Coolers in Orbit

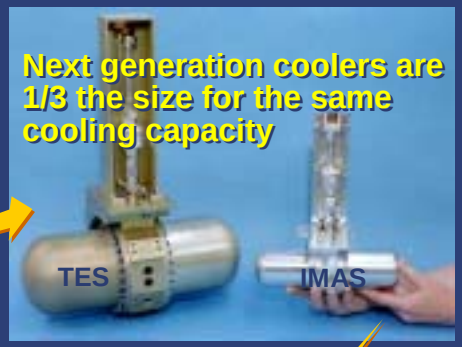
Mini Stirling
(1 in orbit)

AIRS
Cooler
(2 in orbit)

MTI (1 in orbit)

Mini pulse tube (4 in orbit)

Next generation coolers are 1/3 the size for the same cooling capacity



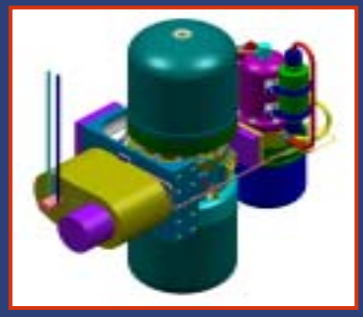
High Capacity Staged
- Only 14 Kg
- 4x capacity of HEC

10K
Cooler

HEC Cooler
Flight Units

6K Cooler

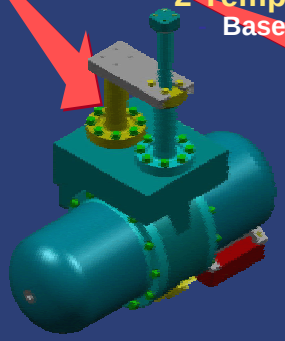
ACTDP



Electronics

Next Generation

2 Temp Staged Coolers
Based on HEC

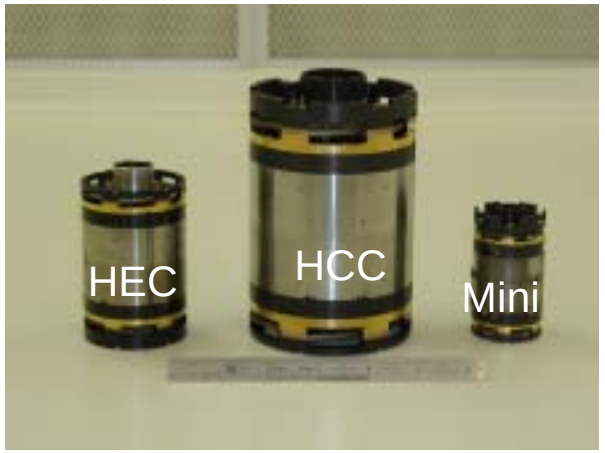


Hybrid
Split

Mini Cooler
1.5 Kg cooler
2/3 mass of mini pulse tube
4x capacity of MPT

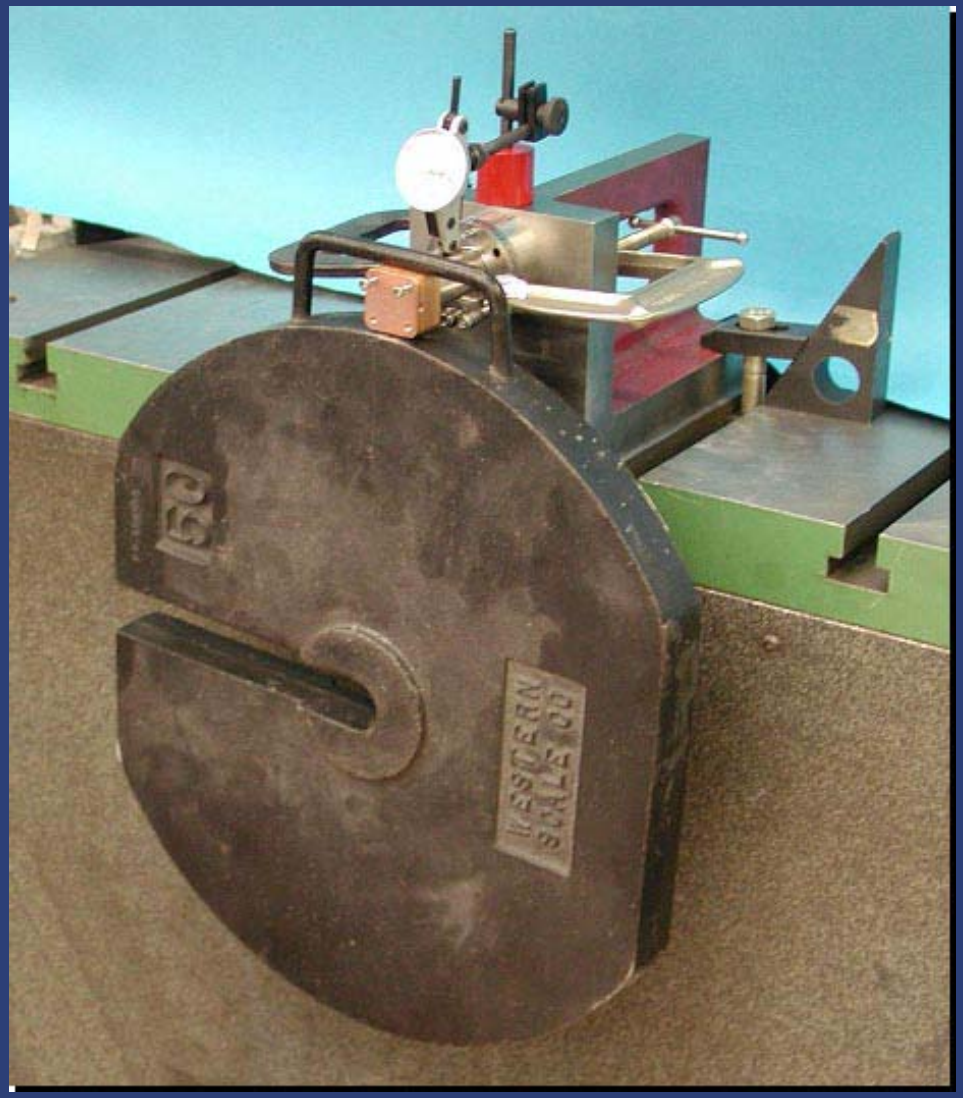
Scaled Balanced Compressors

Compressor Modules



50 Lbs Static Load on Coaxial Pulse Tube Cold Head

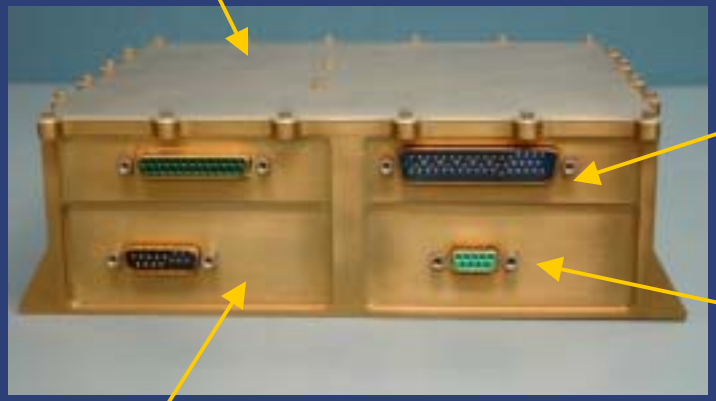
Cold head is very robust



Flight Cooler Components

- HEC Cooler and electronics shown
- ***Components - Electronics, Compressor, Cold head, Harness***

Standard Electronics



Control Slice

Power Amp

Power Supply

Cold Heads

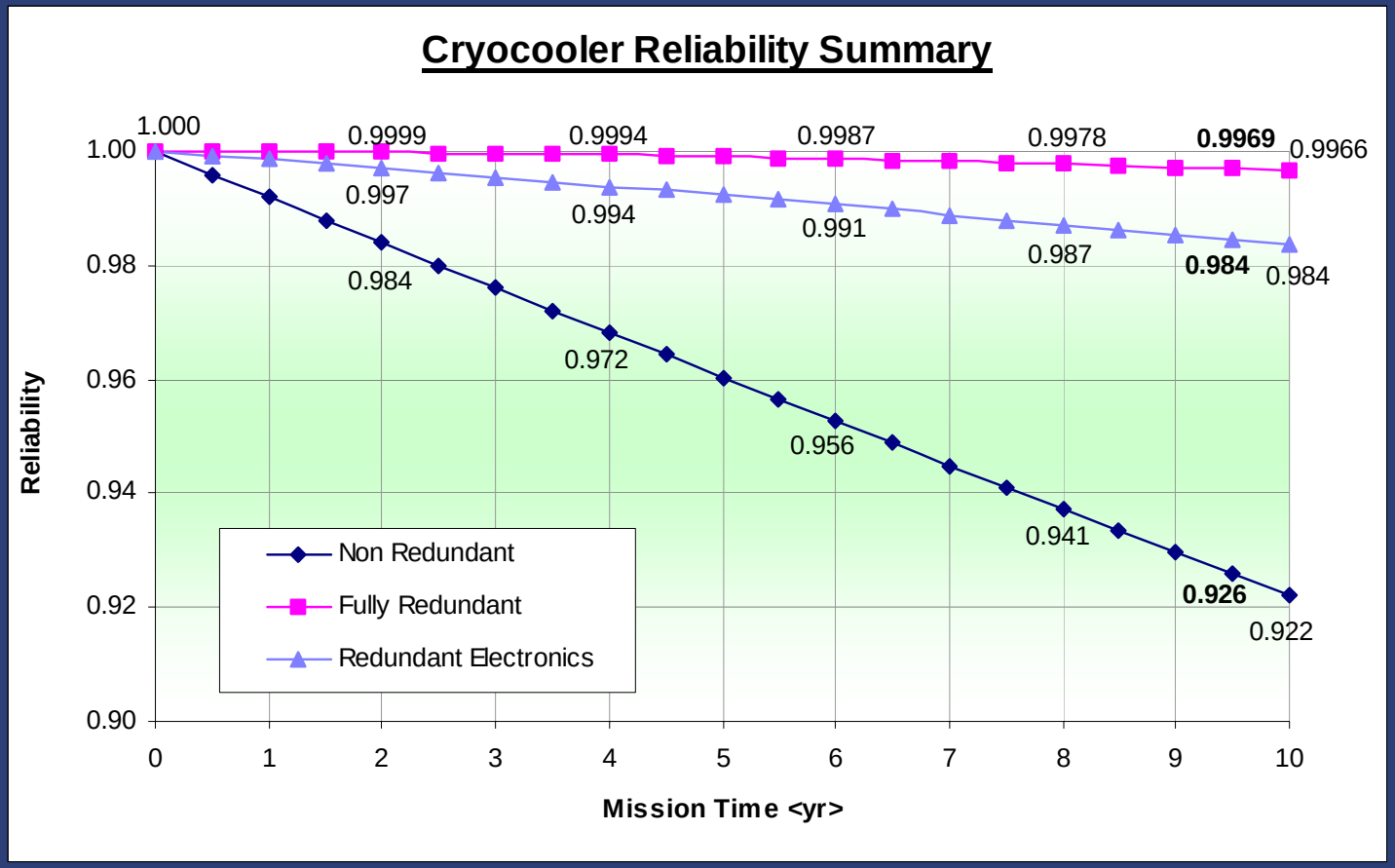
- ***Multiple cold heads matched to compressor and load temperature***

Standard Compressors
A range of sizes

Advantageous Cooler System Features

Feature	Impact on Payload and Spacecraft				
	Cost	Sched	Mass	Risk	
Mechanical Cooler					
Integral pulse tube cold head configuration					Reduced integration complexity. Reduced payload mechanical structure. Reduced payload thermal straps and heat pipes
Integrated heat spreader					Heat spreader integrated into centerplate reduces payload requirement
Pulse tube cold heads					Very robust against launch loads Do not require snubbers
Electronics					
Ripple filter (CE-01 compliant)					Incorporated active filter removes spacecraft need to develop expensive heavy filter
Fully reconfigurable software in orbit					Reduces software schedule risk Reduces operational risk since software upload can cure some hardware faults (e.g. Hyperion)
Autonomous vibration control system					Reduces cooler and payload I&T costs and schedule. Cooler autonomously learns and updates. Does not require measurement and pre-loading of transfer coefficients. Reduces jitter risk on orbit if mechanical structure changes during launch
Engineering diagnostic data					Extensive downloadable diagnostic data including drive current, voltage and accelerometer real time waveforms allows rapid recovery from in orbit failures.

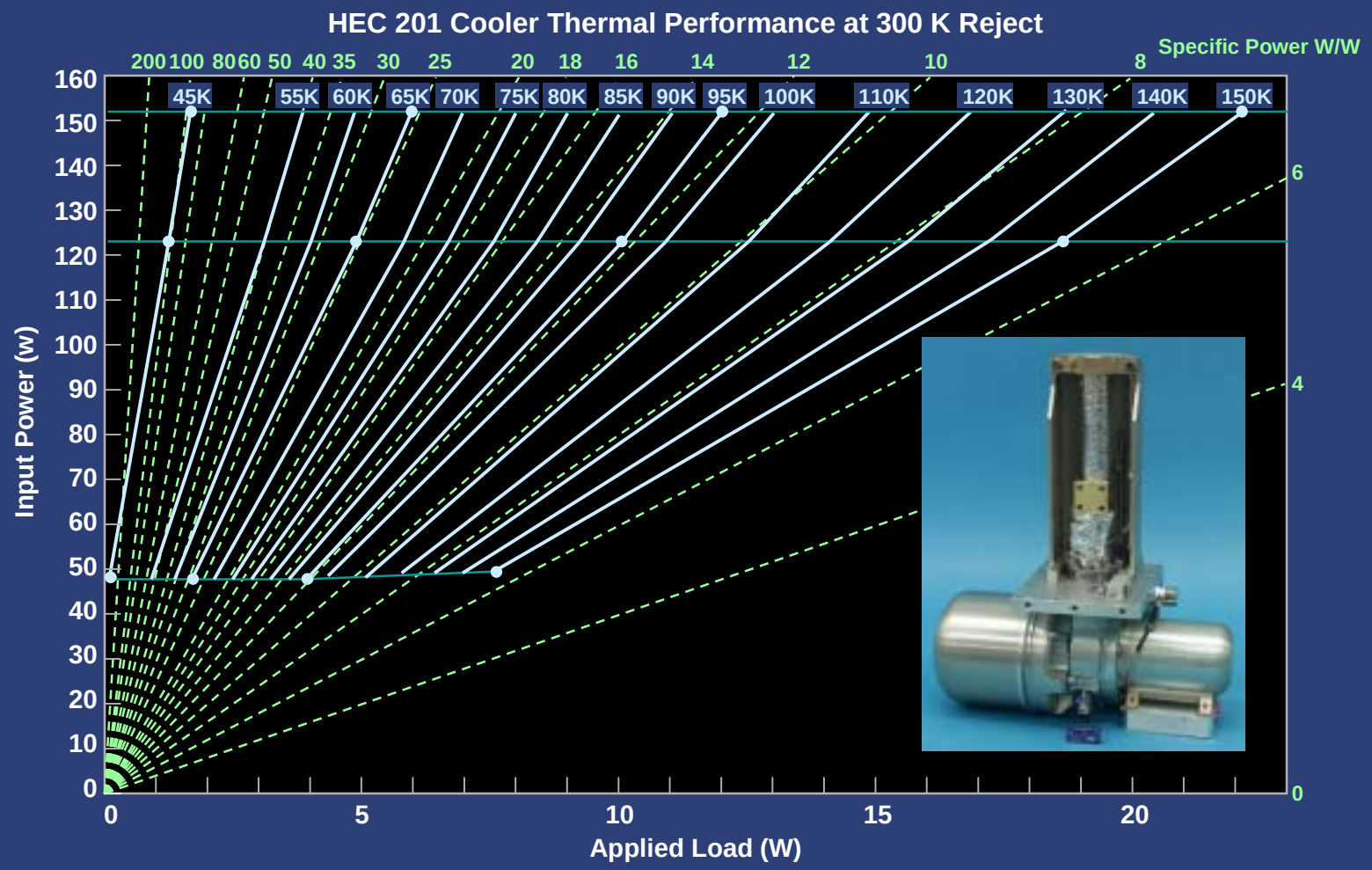
Reliability Performance – Pulse Tube cooler



Single-String System	10 Year Reliability
Cryocooler	0.9223
Cryocooler Control Electronics	0.9355
Mechanical Assembly	0.9858

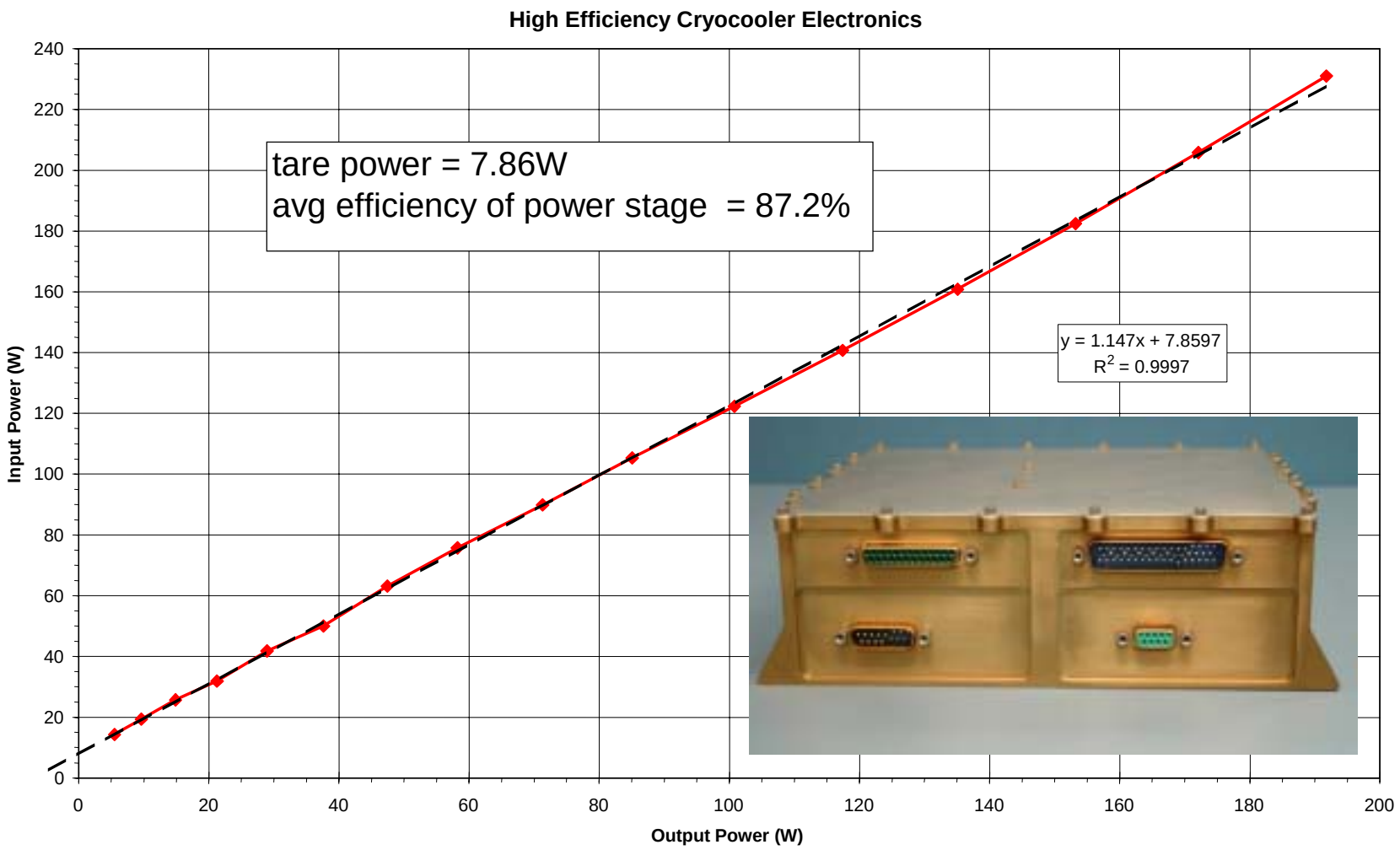
High Efficiency Cryocooler Performance

- *Each cooler provides efficient cooling over a very wide temperature range*
  - *Flight coolers have been delivered for cooling applications at 41K, 60K, 65K, 67K, 95K*



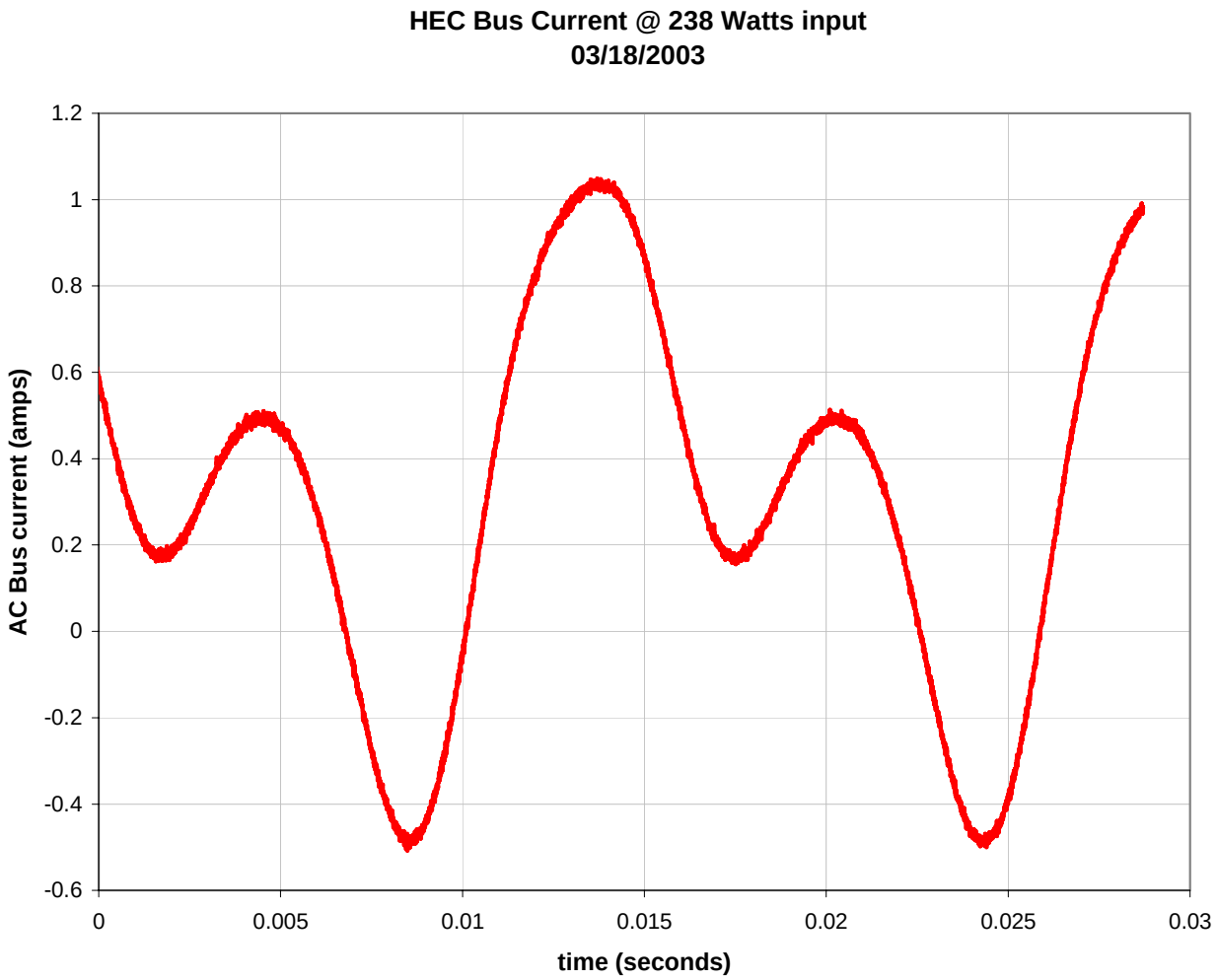
HEC Electronics Efficiency

Very efficient over the complete performance range of delivered power



Active Ripple Control Provides >20dB Attenuation

Active ripple control relieves need for additional ~ 3Kg power bus filter

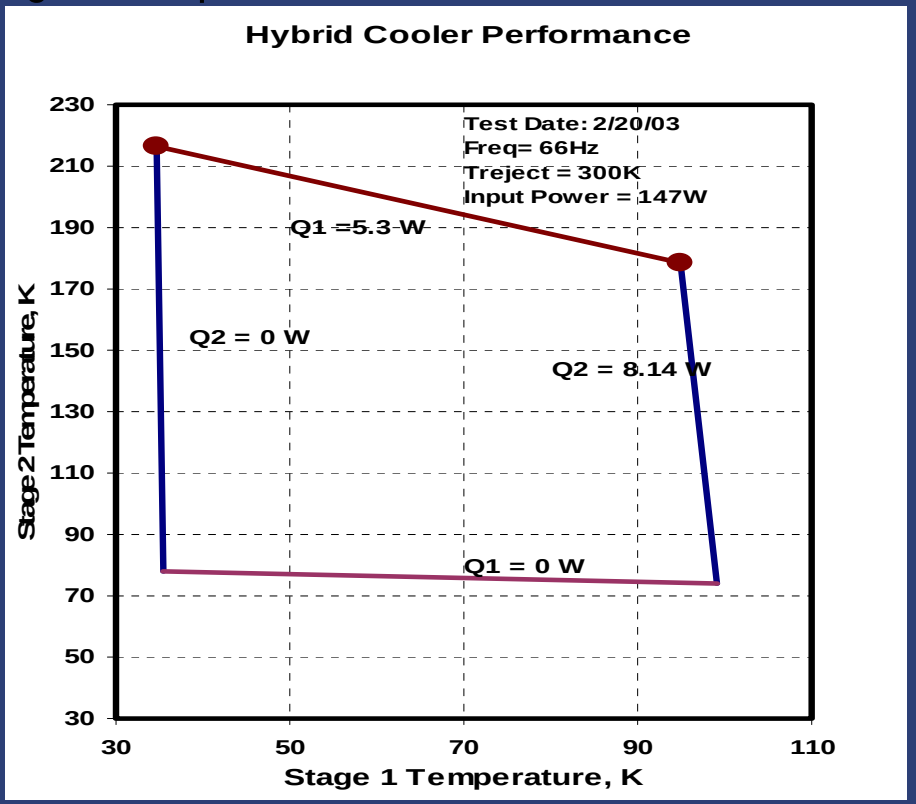


Staged Coolers – Custom Add on to HEC

- ***Two temperature cooling can result in reduced payload power, mass, less hardware and greater system reliability***
  - ñ Typical application is in cooling of focal planes at lower temperatures and simultaneously cooling optics, filters at higher temperatures

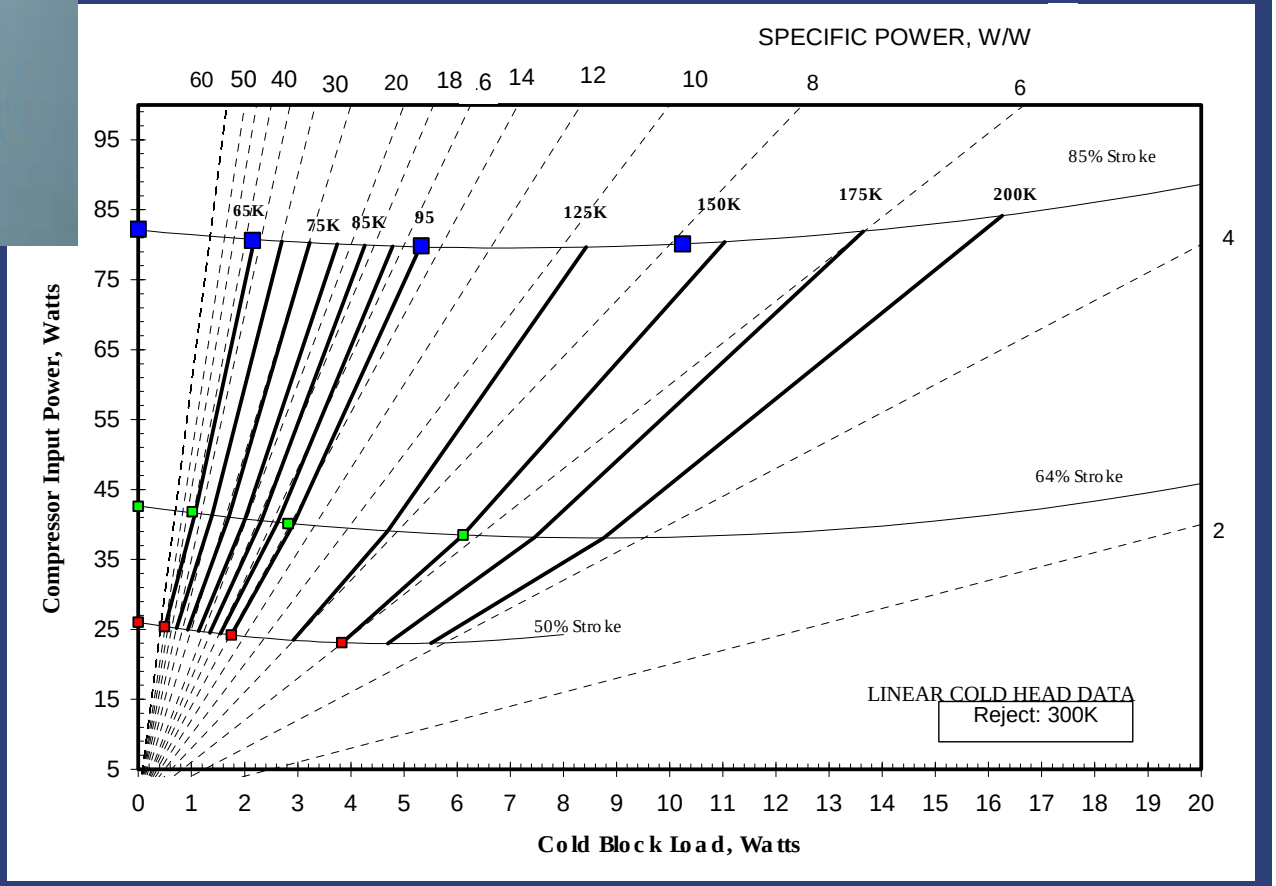
Standard HEC cooler has added remote cold head for cooling optics

Status
Flight Units 6/04



Miniature IR&D Cooler

- ***Miniature cooler has very large capacity/unit mass***
  - ***4x capacity*** of current mini pulse tube coolers
  - ***æ of the mass***



Applications

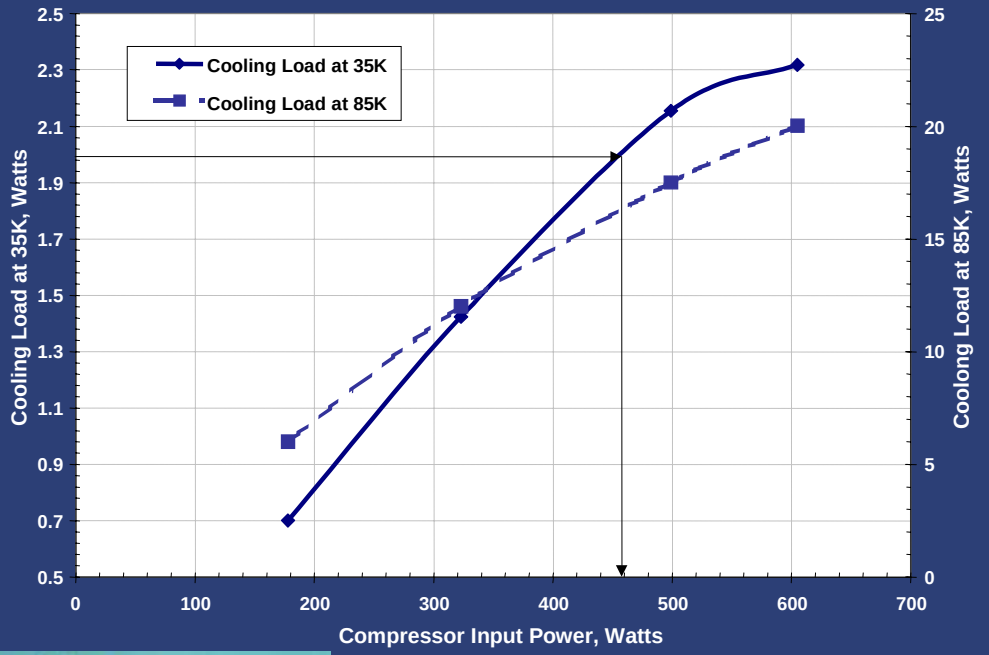
- **Payloads to <40K**

High Capacity Staged Cooler 35K/85K

- ***High capacity coolers are required for large focal planes at low temperature when used with large optics***
  - Cooling payload systems to 35K
  - E.g.
    - (2W@ 35K and 16.7W @85K)

      or

    - .7W @35K and 7W @85K



High Capacity Compressor

HCC Staged Cooler

HCC Status
EM 7/03
(35K/85K Cooler)

ACTDP Cooler - NASA

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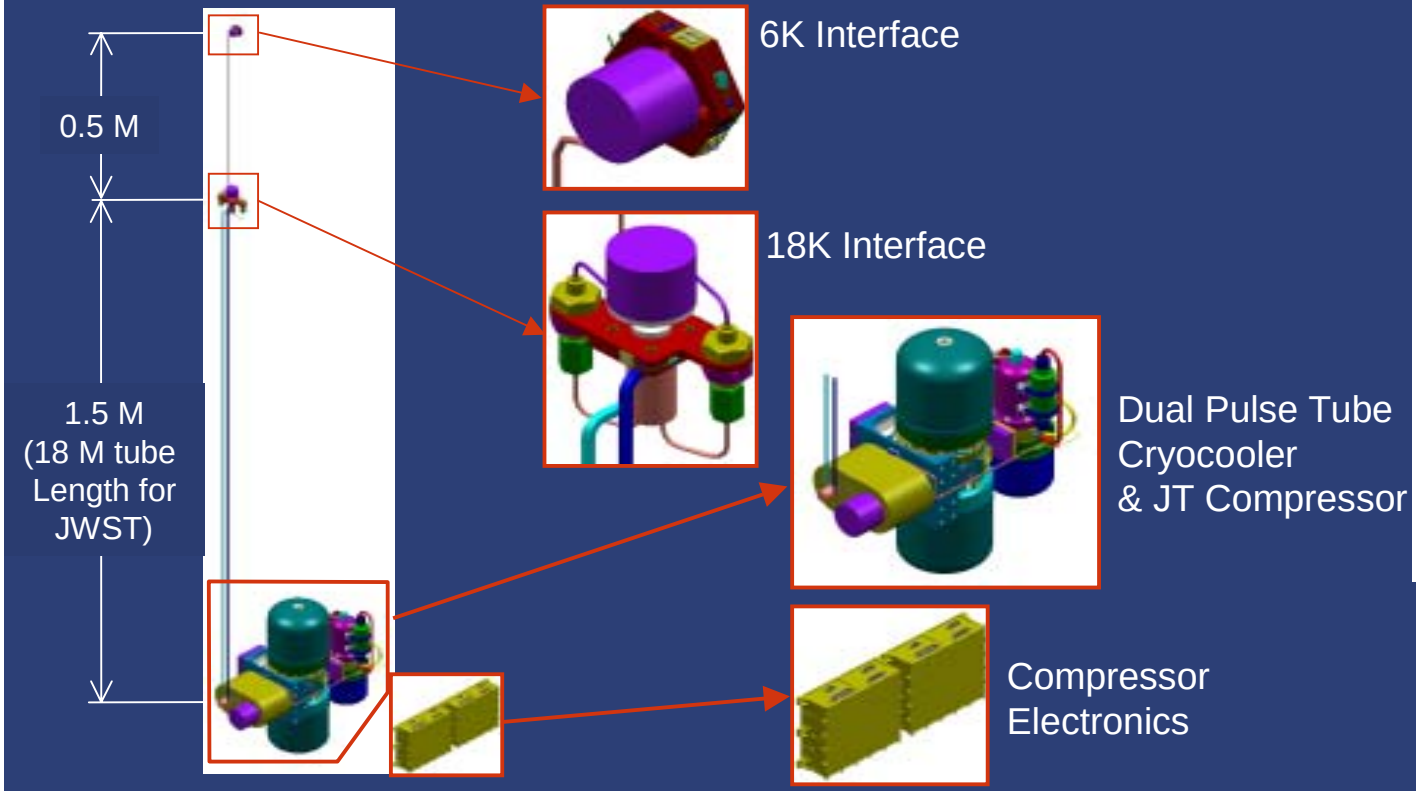
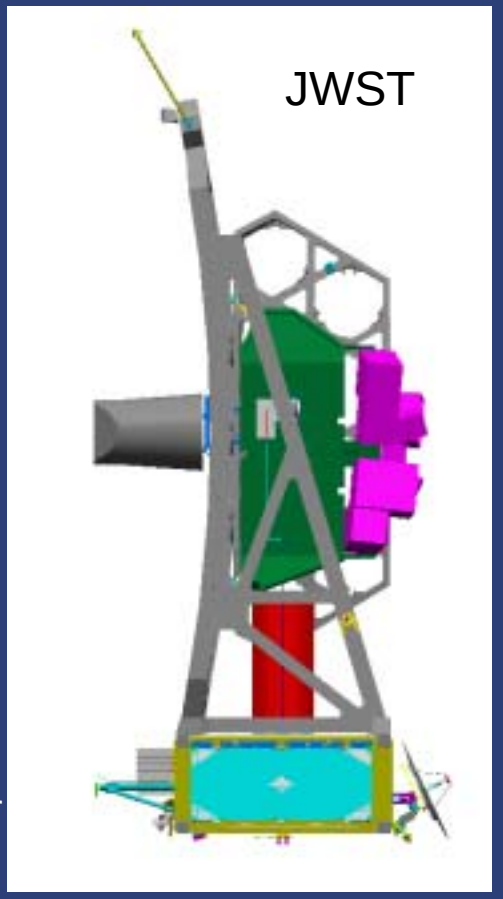
- Provides cooling at remote locations





Cryocooler Summary

- *Pulse Tube cryocoolers are the gold standard for space cooling because of efficiency, producibility and heritage in space*
- *Expansion of capabilities to lower temperatures, higher efficiencies, scaled smaller and larger capacities and to multiple cooling stages will enable many missions*